Compact groups in theory and practice - III. Compact groups of galaxies in the Sixth Data Release of the Sloan Digital Sky Survey

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ABSTRACT

We present the largest publicly available catalogue of compact groups of galaxies identified using the original selection criteria of Hickson, selected from the Sixth Data Release (DR6) of the Sloan Digital Sky Survey (SDSS). We identify 2297 compact groups down to a limiting magnitude of $r = 18$ (~ 0.24 groups degree^{-2}), and 74791 compact groups down to a limiting magnitude of $r = 21$ (~ 6.7 groups degree^{-2}). This represents 0.9% of all galaxies in the SDSS DR6 at these magnitude levels. Contamination due to gross photometric errors has been removed from the bright sample of groups, and we estimate it is present in the large sample at the 14% level. Spectroscopic information is available for 4131 galaxies in the bright catalogue (43% completeness), and we find that the median redshift of these groups is $z_{med} = 0.09$. The median line-of-sight velocity dispersion within the compact groups from the bright catalogue is $\sigma_{LOS} \simeq 230$ km s^{-1} and their typical inter-galactic separations are of order $50 - 100$ kpc. We show that the fraction of groups with interloping galaxies identified as members is in good agreement with the predictions from our previous study of a mock galaxy catalogue, and we demonstrate how to select compact groups such that the interloper fraction is well defined and minimized. This observational dataset is ideal for large statistical studies of compact groups, the role of environment on galaxy evolution, and the effect of galaxy interactions in determining galaxy morphology.

Key words: catalogues - surveys - galaxies: general - galaxies: interactions

1 INTRODUCTION

Galaxies cluster on all scales, and a basic tenet of the $\Lambda-$CDM cosmological paradigm is that structure formation is hierarchical. Consequently, both weak and strong galaxy interactions are expected to be part of the typical life-cycle of a galaxy, and are believed to be among the main drivers in determining a galaxy's star formation history, chemical evolution and morphology.

The majority of $L_\star$ galaxies at $z = 0$ are not found in rich environments and, while many are members of loose groups with a low velocity dispersion, few have nearby large companions with which they are interacting. In contrast, galaxy clusters have a high galaxy number density. However,

the considerable mass of these structures means that their velocity dispersion is of order 1000 km s^{-1}, and thus individual galaxy-galaxy mergers are rare. On the other hand, compact groups (CGs) of galaxies generally have the low velocity dispersions typical of galaxy groups, but with galaxy-galaxy separations small enough for interactions to be significant (e.g., Hickson 1997 and references therein).

Compact groups of galaxies were first quantitatively defined by Hickson (1982), and there now exist several catalogues of compact groups identified using a variety of criteria (e.g., the Digitized POSS CG catalog, Iovino et al. 2003; the Southern CG catalogue, Prandoni et al. 1994; Iovino 2002; CGs in the UZC galaxy catalogue, Focardi & Kelm 2002; the CfA2 redshift survey, Barton et al. 1996; the Las

Campanas redshift survey, Allam & Tucker 2000; the SDSS Commissioning Data, Lee et al. 2004). The identification of genuine groups with only a few members is a difficult problem, and considerable effort has been spent on determining the three dimensional properties of the identified systems (particularly the Hickson Compact Groups) and the effect of interlopers (e.g., Mamon 1986; Hickson & Rood 1988; Walke & Mamon 1989; Hernquist et al. 1995; Ponman et al. 1996).

In this series of papers, we are conducting a homogeneous and systematic study of compact groups using a combination of theoretical and observational galaxy catalogues to provide a statistically-powerful platform from which to probe the effect of galaxy interactions on all aspects of galaxy evolution. In the first paper of this series (McConnachie et al. 2008, hereafter Paper I), we identified compact groups in a mock catalogue constructed from the Millennium Simulation (Springel et al. 2005; De Lucia & Blaizot 2007) and developed a robust understanding of their spatial and dynamical properties. This allowed us to refine the compact group selection criteria to more efficiently identify these systems and understand the sources of contamination in any observed sample. In the second paper of this series (Brasseur et al. 2008, hereafter Paper II), we compared the physical properties of compact group galaxies in our mock catalogue to previous observational studies. We demonstrated consistency with these earlier studies, and we concluded that interloping galaxies misidentified as compact group members have potentially affected our understanding of the influence of interactions on galaxy evolution and morphology.

In this paper, the third in the series, we create the largest observational catalogue of compact group galaxies to date by identifying all such groups in the Sloan Digital Sky Survey Data Release 6, consisting of more than 29 million galaxies to a limiting magnitude of $r = 21$. We make the resulting catalogue of compact groups publicly available through online tables associated with this paper. This catalogue is ideal for large statistical studies of compact groups, the role of environment on galaxy evolution, and the effect of galaxy interactions in determining galaxy morphology. Section 2 details our procedure for the identification of compact groups, Section 3 presents some of the basic observable properties of these systems, and Section 4 summarises our results.

2   COMPACT GROUP FINDING IN SDSS DR6

2.1   Compact group selection criteria

Hickson (1982) define a CG as a group of galaxies with projected properties such that

   (i) $N\,(\Delta\,m = 3) \geq 4$;
   (ii) $\theta_N \geq 3\,\theta_G$;
   (iii) $\mu_e \leq 26.0$ mags arcsec^{-2}.

$N\,(\Delta\,m = 3)$ is the number of galaxies within 3 magnitudes of the brightest galaxy and μ_e is the effective surface brightness of these galaxies, where the total flux of the galaxies is

averaged over the smallest circle which contains their geometric centres and has an angular diameter θ_G. θ_N is the angular diameter of the largest concentric circle which contains no additional galaxies in this magnitude range or brighter. All magnitudes and surface brightnesses are measured in the $r-$band. We hereafter refer to these criteria collectively as the 'Hickson criteria'.

Since the Hickson criteria were first introduced, there has been considerable debate regarding the physical nature of the galaxy associations identified (e.g., Mamon 1986; Hickson & Rood 1988; Walke & Mamon 1989), and determining the three dimensional reality of systems identified as compact groups has remained a focus of theoretical and observational study (e.g., Hernquist et al. 1995; Ponman et al. 1996). To address this issue, in Paper I of this series, we applied the Hickson criteria to an all-sky mock galaxy catalogue, with a limiting magnitude of $r = 18$, to determine the physical reality of the systems that these criteria identify. We found that the identified galaxy associations preferentially had a three-dimensional linking length, $l \leq 200h^{-1}$ kpc (comoving, where $H_o = 100\,h\,\mathrm{km\,s^{-1}Mpc^{-1}}$). Defined in this way, $\sim 30\%$ of all the identified galaxy associations were "genuine" compact groups, while the remaining systems were found to contain one or more interloping galaxies and were treated as contamination. We found that this physically well-defined sample of genuine compact groups could be identified with greatly reduced levels of contamination by modifying the original Hickson criteria to select more isolated groups and higher surface brightness groups: by changing the latter from $\mu_e \leq 26.0$ to $\mu_e \leq 25.0, 24.0$ and $23.0\,\mathrm{mags\,arcsec^{-2}}$, the contamination rates decrease from $\sim 71\%$ to 57%, 44% and 33%, respectively. This is in general agreement with the search strategies adopted by some earlier surveys for compact groups (e.g., Iovino et al. 2003; Lee et al. 2004) which modified these criteria to try to reduce contamination.

In what follows, we apply the Hickson criteria in their original form to create our main compact group catalogues. Sub-catalogues can be created from this publicly-available resource, with different cuts applied in, for example, surface brightness, isolation or brightest members, depending upon the requirements of the specific project being undertaken (e.g., statistical size of dataset versus expected contamination rates).

2.2   The SDSS DR6 galaxy catalogue

The SDSS DR6 (Adelman-McCarthy et al. 2008) catalogue contains photometric parameters for ~ 287 million unique objects (stellar and galactic) over ~ 9583 degrees^2 ($\sim 23\%$ of the sky), of which approximately 1.27 million objects have associated spectra. As such, SDSS DR6 is presently the largest publically available photometric and spectroscopic dataset of galaxies.

Some previous searches for compact groups of galaxies have identified compact groups in spectroscopic galaxy catalogues through linking-length analyses in projection and redshift space (following Huchra & Geller 1982; e.g., the CfA2 redshift survey, Barton et al. 1996; the Las Campanas red-

shift survey, Allam & Tucker 2000; the UZC galaxy catalogue, Focardi & Kelm 2002; the SDSS DR5 and DR6, Deng et al. 2007, 2008). However, spectroscopic galaxy catalogues are necessarily much smaller than corresponding photometric catalogues, and one of the main motivations for this work is to obtain a statistically large sample of compact groups for subsequent study. Further, compact groups generally have small angular extent ($\lesssim 1$ arcmin), and the SDSS suffers from fiber collisions for objects which are very close together (Strauss et al. 2002), meaning that not all members of a compact group can be expected to possess redshift information. We therefore choose not to use the spectroscopic catalogue for our compact group search, and instead identify compact groups based upon their projected photometric properties.

We extract all objects identified as a galaxy from the SDSS DR6 catalogue, imposing a bright-end limit on the r-band magnitude at $r = 14.5$, since the automated deblending of galaxies is known to become unreliable above this limit (Strauss et al. 2002). We do not consider any objects which have been flagged as "SATURATED" and/or "DEBLENDED_AS_PSF". The former removes all objects which appear saturated, implying that their photometric parameters are unreliable. The latter removes any point sources initially identified as part of larger photometric structures; they are therefore unlikely to be galactic in nature. The exclusion of galaxies with either of these two flags decreases the size of our dataset by 3.9%.

We construct two different datasets from SDSS DR6, corresponding to two different faint-end magnitude limits of $r = 18$ and $r = 21$. The former is identical to the magnitude limit of the mock galaxy catalogue discussed in Papers I and II, and ensures that the observational and mock catalogues can be robustly compared. The latter corresponds to a level above which photometric completeness and star-galaxy separation are reliable (Lupton et al. 2001; Abazajian et al. 2004), and ensures a large reliable dataset for statistical studies. All magnitudes are corrected for foreground Galactic extinction.

Our final $14.5 \leq r \leq 18.0$ galaxy catalogue (hereafter referred to as Catalogue A) has $1\,107\,622$ members. Our final $14.5 \leq r \leq 21.0$ galaxy catalogue (hereafter referred to as Catalogue B) has $29\,065\,010$ members.

2.3 Application of the search algorithm

We apply a search algorithm for compact groups by considering each galaxy in the magnitude-limited catalogues in turn. The galaxies in the immediate vicinity of the target galaxy (selected within a very generous 1 degree radius from the target galaxy) are initially considered as possible group members. The geometric centre of the group, its radius, magnitude range, surface brightness and distance to the nearest non-member galaxy in the appropriate magnitude range, are calculated. This procedure is repeated, with the most distant member galaxy from the target galaxy being eliminated each round, until a group of galaxies is found which satisfies the Hickson criteria. Failing this, if fewer than 4 galaxies remain in the group, we start the procedure afresh by con-

sidering the next galaxy in the catalogue (unless that galaxy has been determined to be a member of a previous compact group). This is an identical procedure to that which was applied to the mock catalogue in Paper I.

To speed up this computationally intensive algorithm, Catalogue B is split into 34 sub-areas and the algorithm applied separately to each sub-area. Catalogue A is split into 5 sub-areas. Compact groups which happen to lie on the borders of these sub-areas could conceivably elude detection. However, the maximum diameter of our compact groups is found to be ~ 2 arcmin and so only groups lying within a negligible area compared to the total survey area will not be detected.

In each dataset we identify all groups irrespective of the magnitude of the brightest galaxy; for groups where the brightest member is less than 3 magnitudes brighter than the magnitude limit of the catalogue, this means that the isolation criteria may not be met when nearby galaxies fainter than the magnitude limit of the catalogue are considered. This relaxation of the original Hickson criteria increases the number of groups identified significantly and allows for direct comparisons with the mock catalogue studied in Paper I and II which uses the same selection criteria.

In total, we initially identify 3108 compact groups of galaxies in Catalogue A and 74791 compact groups in Catalogue B, consisting of a total of 13233 and 313508 individual objects, respectively.

2.4 Contamination and Health Warnings

Obvious contamination in the compact group catalogues arises as a result of errors in the photometric galaxy catalogue on which the search is conducted. In each panel of Figure 1 is an example of a source of contamination for this study: (i) some objects which are classified as galaxies by the SDSS classification algorithm appear stellar on visual inspection; (ii) some objects are classified as reasonably bright sources but on inspection it is obvious that the magnitude assigned is grossly incorrect; (iii) fragments of satellite trails are occasionally classified as galaxies; (iv) some objects are found very close to saturated objects and have unreliable photometry. The largest source of contamination for this study, however, comes from (v) incorrect de-blending of extended galaxies into many smaller sources subsequently identified as galaxies.

Note that when discussing contamination, we do not at this stage consider redshift information for galaxies in our groups for which spectroscopic data is available; we consider only the photometric properties from which the groups were identified. Spectroscopic data and the identification of interloping groups with discordant redshift information are considered in detail in Section 3.

2.4.1 Groups in Catalogue A

To remove the sources of contamination from groups in Catalogue A, AWM, DLP and SLE independently visually inspected all 13233 objects belonging to groups in Catalogue A
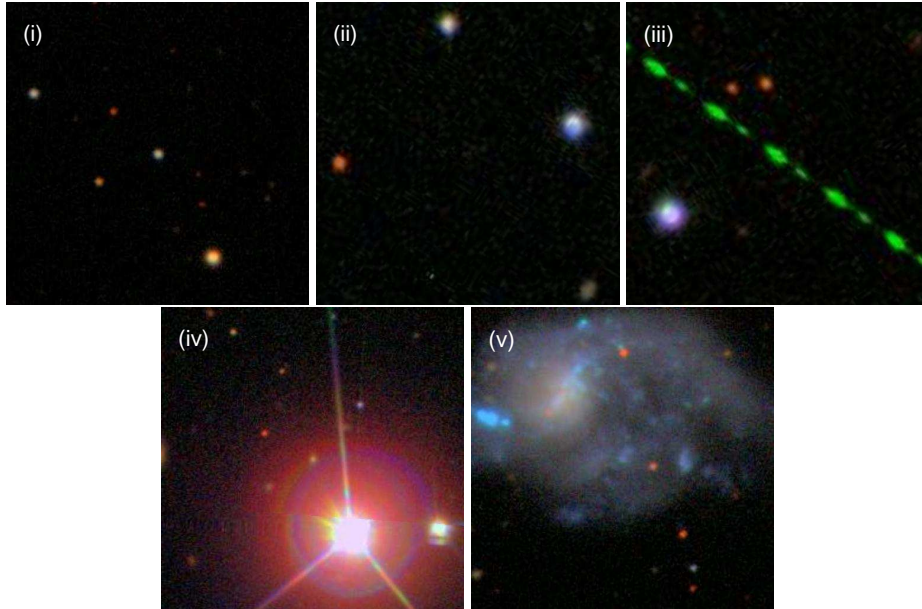
Figure 1. In the centre of each panel is an example of a typical source of contamination in the SDSS DR6 which affects this study: (i) a stellar source misclassified as a galaxy; (ii) an object classified as a bright ($r \sim 17$) galaxy but for which there is no identifiable source/very faint source; (iii) a fragment of a satellite trail identified as a chain of several galaxies; (iv) an object (perhaps galactic) close to a saturated object; (v) a large, extended galaxy which has been de-blended into many component objects, many of which have been independently classified as galactic. The latter is the primary source of contamination in our search for compact groups, particularly at bright magnitudes.

and recorded their findings. If each member of a group appeared galactic in nature, and did not appear to have any gross errors in its $r-$band photometry, then the group was marked as "genuine"; if one or more members of a group appeared to have been incorrectly classified as galactic, or the $r-$band magnitude of one or more members appeared grossly incorrect, the group was marked as "spurious"; if it was unclear if a group was genuine or not, it was marked "for further inspection". This was done independently by the three co-authors and, once completed, the three sets of results were collated.

All groups marked as "genuine" by all three co-authors were classified as genuine and kept in the group catalogue; all groups marked as "spurious" by all three co-authors were accepted as spurious and rejected from the catalogue; any groups where the co-authors were not unanimous in their independent classifications were re-inspected and kept or rejected from the catalogue depending on the result of this re-inspection; any group marked as "for further inspection" by *any* co-author was re-inspected, and kept or rejected from the catalogue depending on the result of this re-inspection. In addition, a few groups were found to contain a galaxy brighter than the bright-end limit of the catalogue. These few groups were additionally removed from the sample.

The final list of groups from Catalogue A contains 2297 compact groups (9713 galaxies). Thus 26% of the groups in Catalogue A originally identified by our algorithm as a compact group in SDSS DR6 were found to contain a member or member(s) for which the automated photometric classifi-

cation procedure was flawed, usually in one of the ways indicated in Figure 1 (over half of all contamination was due to *(v)* incorrect deblending, approximately one-third was due to *(ii)* grossly incorrect magnitudes, and the remaining fraction was due to the other types of contamination). However, due to the independent visual inspection of all members of groups in Catalogue A by three different co-authors, the level of contamination in the final version of the group catalogue is negligible.

2.4.2 Groups in Catalogue B

We identified 313508 individual objects belonging to groups found in Catalogue B. It is impractical to visually inspect each object in the same way as above to determine if each group is genuine. Instead, we seek to quantify the contamination fraction by selecting a random 1500 compact groups and visually inspecting each member (6252 individual objects).

Of the 1500 compact groups inspected, ~ 205 appear to contain a member or members which had been incorrectly classified by the SDSS DR6 automated algorithms. Thus, we estimate that the groups identified in Catalogue B contain contamination at the 14 % level. This is considerably lower than for Catalogue A, and reflects the fact that Catalogue B contains a smaller fraction of very bright galaxies (for which the de-blending algorithm runs into difficulty and which provides the primary source of contamination). Among the groups in Catalogue B containing bright galax-

ies, the contamination level can be expected to be similar to the initial contamination level of groups in Catalogue A. We have additionally flagged those groups in Catalogue B which contain objects which belong to groups originally identified in Catalogue A and which were subsequently classified as contamination (Section 2.5).

The final list of groups from Catalogue B contains 74791 compact groups (313508 galaxies) and has an estimated contamination fraction of 14%.

We emphasise that the photometric parameterisation of all the objects in our published catalogues of compact groups is from the main SDSS DR6 reduction. Any errors in the SDSS DR6 photometric reduction procedure will therefore propagate through to the compact group catalogues. Any errors not discussed above which exist in the SDSS DR6 reduction will potentially also exist in the compact group catalogue. The final list of groups from Catalogue A only contains bright galaxies, $r \leq 18$, with negligible contamination due to gross photometric errors. The list of groups from Catalogue B is much larger and includes galaxies down to $r = 21$ and has contamination due to poor photometric classification at the 14% level. As discussed in Section 2.2, groups are selected irrespective of the magnitude of their brightest member galaxy, and for groups where the brightest member is less than 3 magnitudes brighter than the magnitude limit of the catalogue, this means that the strict Hickson isolation criteria may not be met when nearby galaxies fainter than the magnitude limit of the catalogue are considered. For groups from Catalogue A, the brightest member galaxy has $r \leq 15$ in 189 groups (8%); for groups in Catalogue B, the brightest member galaxy has $r \leq 18$ in 20057 groups (27%).

2.5 Catalogue Format

Tables 1 and 2 list the properties of compact groups found in Catalogues A and B, respectively. Tables 3 and 4 list the properties of the individual member galaxies for each group in Catalogues A and B, respectively. In each Table, only lines corresponding to the first 12 compact groups in each catalogue are listed. Full electronic versions of these Tables can be downloaded through the MNRAS website.

In Tables 1 and 2, compact groups are listed in order of descending surface brightness (results from Paper I suggest that groups with a higher surface brightness are less likely to contain interlopers). The columns of Tables 1 and 2 are as follows:

- *Column 1* - Group ID (11 characters) Ascending numerical order (5 digit numbers) prefixed by "SDSSCGA/B" depending on the catalogue;
- *Column 2, 3, 4* - Right Ascension (J2000). Refers to geometrical centre of group (hexadecimal format);
- *Column 5, 6, 7* - Declination (J2000). Refers to geometrical centre of group (hexadecimal format);
- *Column 8* - Number of members in the group, n_{mem};

- *Column 9* - Group surface brightness in the $r-$band, defined by the Hickson criteria (mags arcsec^{-2});
- *Column 10* - Group radius, defined by the Hickson criteria (arcmins);
- *Column 11* - Distance to the next nearest non-member galaxy in the galaxy catalogue, in the appropriate magnitude range, measured from the group centre in units of the group radius;
- *Column 12* - $r-$band apparent Petrosian magnitude of brightest group galaxy, corrected for foreground Galactic extinction;
- *Column 13* - Number of galaxies in the group with a spectroscopic redshift;
- *Column 14* - Redshift of group (if available). If only one galaxy has a spectroscopic redshift, then that is adopted as the group redshift. If multiple members of the group have redshifts, the mean redshift is listed. Only considers groups with $\Delta v \leq 1000 \, \mathrm{km \, s^{-1}}$ (see Section 3.1.2 for definition). Only considers galaxies with $z_{conf} \geq 0.7$ (see below for definition);
- *Column 15 (online Table 2 only).* Flag indicating if the group contains members which were originally identified as belonging to groups in Catalogue A which were subsequently identified as containing contamination ($flag = 1$ if true, 0 if false).

The columns of Tables 3 and 4 are as follows:

- *Column 1* - Galaxy ID in the group catalogue. Format is "*group.gal*", where "*group*" corresponds to Group ID in Tables 1 and 2 (group order is the same as Tables 1 and 2) and "*gal*" is a number from $i = 1...n_{mem}$. Galaxies in each group are listed in order of increasing $r-$band apparent magnitude;
- *Column 2* - SDSS ObjID. Unique identifier of object in the SDSS database which can be used to retrieve all information stored in the SDSS on the galaxy;
- *Column 3, 4, 5* - Right Ascension (J2000). Galaxy position (hexadecimal format);
- *Column 6, 7, 8* - Declination (J2000). Galaxy position (hexadecimal format);
- *Column 9* - $r-$band apparent Petrosian magnitude of galaxy, corrected for foreground Galactic extinction;
- *Column 10* - $(g-r)$ colour of galaxy, corrected for foreground Galactic extinction. No $k-$correction has been applied;
- *Column 11* - SDSS SpecObjID (if available). Unique identifier of the SDSS spectrum for this galaxy;
- *Column 12* - SDSS z_{conf} (if applicable). If a spectrum exists for the galaxy, this parameter indicates how reliable the derived redshift is. 0 (poor) $\leq z_{conf} \leq 1$ (excellent);
- *Column 13* - Redshift (if available).

Figure 2 shows images of the twelve compact groups found in Catalogue A with the highest central surface brightnesses. It is striking that these twelve groups are generally dominated by red galaxies. In Paper II, we found that compact group galaxies identified in the mock catalogue were predominantly "red and dead" galaxies. While these brightest groups appear to be consistent with this prediction, it is

ID	α (J2000)			δ (J2000)			n_{mem}	μ	θ_G	θ_N/θ_G	r_{max}	n_z	z
SDSSCGA00001	14	49	34.3	+11	14	53.4	4	20.991	0.22	4.63	15.01	1	0.055
SDSSCGA00002	2	14	4.5	+13	18	54.3	4	21.238	0.28	3.30	14.81	1	0.060
SDSSCGA00003	23	54	13.5	-10	23	17.2	4	21.279	0.16	5.96	16.42	1	0.079
SDSSCGA00004	15	25	53.7	+5	44	17.8	4	21.501	0.16	18.64	15.82	0	
SDSSCGA00005	23	33	23.6	-1	8	43.8	4	21.519	0.29	5.19	14.53	1	0.091
SDSSCGA00006	21	40	17.4	-8	4	11.7	4	21.566	0.14	4.31	16.84	0	
SDSSCGA00007	8	24	31.6	+20	27	28.5	4	21.585	0.19	9.26	15.77	2	0.109
SDSSCGA00008	16	10	2.6	+5	54	53.5	4	21.747	0.31	3.74	14.89	1	0.065
SDSSCGA00009	12	3	12.9	+57	53	39.2	4	21.755	0.32	7.84	14.95	2	0.034
SDSSCGA00010	16	26	50.4	+25	53	34.7	4	21.913	0.20	7.58	16.01	2	0.111
SDSSCGA00011	16	21	56.5	+25	41	20.1	4	22.054	0.21	5.84	16.48	3	0.100
SDSSCGA00012	7	44	42.7	+16	55	21.6	4	22.130	0.29	3.40	15.36	0	

Table 1. Compact groups identified in Catalogue A, ranked in order of decreasing surface brightness. This table has 2297 rows, of which only the first 12 rows are reproduced here. See Section 2.5 for a description of each column.

ID	α (J2000)			δ (J2000)			n_{mem}	μ	θ_G	θ_N/θ_G	r_{max}	n_z	z
SDSSCGB00001	14	12	15.8	+35	50	59.0	4	19.730	0.08	14.67	16.01	1	0.059
SDSSCGB00002	16	15	45.9	+54	40	19.6	4	19.791	0.10	48.11	15.35	0	
SDSSCGB00003	13	25	10.4	+17	3	8.0	4	20.333	0.13	35.94	15.05	0	
SDSSCGB00004	11	44	12.1	+27	0	12.0	4	20.347	0.09	7.32	16.41	1	0.093
SDSSCGB00005	7	55	30.4	+10	25	51.8	4	20.366	0.14	17.32	15.11	0	
SDSSCGB00006	9	4	34.9	+14	35	42.4	5	20.547	0.19	15.32	15.14	1	0.050
SDSSCGB00007	13	54	19.5	+7	23	8.3	4	20.577	0.12	13.62	15.62	1	0.075
SDSSCGB00008	11	4	36.7	+6	23	46.1	4	20.725	0.13	24.23	15.43	1	0.032
SDSSCGB00009	16	28	28.3	+41	13	6.2	4	20.749	0.21	17.08	14.61	1	0.028
SDSSCGB00010	16	13	18.9	+50	2	12.7	4	20.805	0.04	7.93	18.78	0	
SDSSCGB00011	14	29	17.4	-3	9	13.3	4	20.889	0.16	3.33	16.03	1	0.082
SDSSCGB00012	13	39	44.9	+45	39	58.9	4	20.966	0.05	14.28	18.08	0	

Table 2. Compact groups identified in Catalogue B, ranked in order of decreasing surface brightness. This table has 74791 rows, of which only the first 12 rows are reproduced here. See Section 2.5 for a description of each column.

important to emphasise that bluer, later-type galaxies are present in significant numbers in these catalogues. Figure 3 shows a selection of compact groups which were selected for their visual impact and to show the range and variety of galaxy types that are present in these catalogues.

2.6 Comparison with Lee et al. (2004)

Lee et al. (2004) searched for compact groups of galaxies in the Early Data Release (EDR) of the SDSS (Stoughton et al. 2002) using all galaxies with $14.0 \leq r \leq 21.0$. They used the Hickson criteria, modified so that only groups with $\mu \leq 24 \, \text{mags arcsec}^{-2}$ were considered. As an independent check on the success of our search algorithm and the reproducibility of our results, we now determine if Catalogue B contains those groups identified by Lee et al. (2004). However, not all of the Lee et al. groups will be identified in the SDSS DR6 due to differences in the underlying catalogues. In particular,

• the photometric calibration for the SDSS $ugriz$ system has been updated between the SDSS EDR and SDSS DR6 (see Adelman-McCarthy et al. 2008 and references therein).
• Lee et al. (2004) do not use the SDSS star-galaxy classification algorithm, and instead use a different classification scheme from Scranton et al. (2002), which is itself based

upon an earlier processing of the SDSS EDR than the published version.

To take the above considerations taken into account, we search the SDSS DR6 for those objects with the best positional coincidence to the individual member galaxies of the Lee et al. (2004) groups, as given in their Table 2. This allows us to derive the photometric properties of the Lee et al. (2004) groups using the SDSS DR6 catalogue. We find that

(i) Of the 175 groups (more than 3 members) identified in Lee et al. (2004), good positional matches to objects in the SDSS DR6 (better than 0.5 arcsecs) are found for all members of 164 groups. We therefore do not consider the 11 remaining groups further, since it is not possible for us to have found these groups using the SDSS DR6;

(ii) Of the remaining 164 groups, 13 groups have at least one member which is best matched to an object flagged as stellar in DR6. Thus we do not examine these 13 groups further;

(iii) Of the remaining 151 groups, 2 groups have members which are flagged as "DEBLENDED_AS_PSF". Thus these 2 groups will not be identified in our catalogue (Section 2.2) and we do not consider them further;

(iv) Of the remaining 149 groups, 1 group has a member with $r = 14.41$, brighter than our bright-end limit. Thus this group will not be identified in our catalogue and we do not consider it further;

ID	ObjID (SDSS)	α (J2000)			δ (J2000)			r	$(g-r)$	SpecObjID (SDSS)	z_{conf}	z
SDSSCGA00001.1	587736807771078936	14	49	34.5	+11	14	53.2	15.01	0.86	0		
SDSSCGA00001.2	587736807771078937	14	49	34.9	+11	14	55.2	15.29	0.82	0		
SDSSCGA00001.3	587736807771078935	14	49	34.2	+11	14	44.0	16.23	1.07	482677981936877568	0.999	0.055
SDSSCGA00001.4	587736807771078938	14	49	33.6	+11	15	1.2	17.29	0.97	0		
SDSSCGA00002.1	587724198822412473	2	14	3.9	+13	18	47.2	14.81	1.08	120694126130757632	0.999	0.060
SDSSCGA00002.2	587724198822477903	2	14	5.1	+13	18	39.5	15.07	0.87	0		
SDSSCGA00002.3	587724198822477905	2	14	5.0	+13	19	2.3	15.52	1.12	0		
SDSSCGA00002.4	587724198822412475	2	14	4.2	+13	19	8.1	17.71	0.68	0		
SDSSCGA00003.1	587727225689538694	23	54	13.2	-10	23	11.0	16.42	0.85	182901462030876672	0.999	0.079
SDSSCGA00003.2	587727225689538695	23	54	13.5	-10	23	8.7	16.69	1.03	0		
SDSSCGA00003.3	587727225689538696	23	54	13.5	-10	23	23.6	16.77	0.81	0		
SDSSCGA00003.4	587727225689538697	23	54	13.8	-10	23	25.5	16.86	0.79	0		
SDSSCGA00004.1	587730023333625957	15	25	53.9	+5	44	9.7	15.82	0.99	0		
SDSSCGA00004.2	587730023333625958	15	25	53.7	+5	44	27.7	17.20	1.09	0		
SDSSCGA00004.3	587730023333625960	15	25	53.4	+5	44	10.2	17.57	0.84	0		
SDSSCGA00004.4	587730023333625959	15	25	53.8	+5	44	23.7	17.83	0.95	0		
SDSSCGA00005.1	588015507655819398	23	33	22.7	-1	8	54.9	14.53	0.97	0		
SDSSCGA00005.2	588015507655819395	23	33	24.4	-1	8	54.2	16.16	1.07	0		
SDSSCGA00005.3	588015507655819396	23	33	23.6	-1	8	35.0	16.33	1.05	108308961144340480	1.000	0.091
SDSSCGA00005.4	588015507655819397	23	33	23.6	-1	8	31.0	17.04	0.84	0		
SDSSCGA00006.1	587727213348454817	21	40	17.3	-8	4	14.8	16.84	1.36	0		
SDSSCGA00006.2	587727213348454819	21	40	16.9	-8	4	8.9	16.95	0.46	0		
SDSSCGA00006.3	587727213348454818	21	40	17.5	-8	4	17.4	17.22	0.83	0		
SDSSCGA00006.4	587727213348454820	21	40	17.8	-8	4	5.7	17.87	0.93	0		
SDSSCGA00007.1	587739407832580481	8	24	32.1	+20	27	26.2	15.77	1.22	586541553271439360	1.000	0.109
SDSSCGA00007.2	587739407832580480	8	24	31.9	+20	27	39.4	16.77	1.18	542631292303310848	0.998	0.110
SDSSCGA00007.3	587739407832580484	8	24	31.5	+20	27	27.8	17.01	1.59	0		
SDSSCGA00007.4	587739407832580482	8	24	31.1	+20	27	20.7	17.48	0.98	0		
SDSSCGA00008.1	587736543103877672	16	10	2.5	+5	55	1.4	14.89	0.81	513360322849931264	0.999	0.065
SDSSCGA00008.2	587736543103877675	16	10	1.5	+5	54	59.2	15.74	0.96	0		
SDSSCGA00008.3	587736543103877673	16	10	3.5	+5	54	48.4	16.24	0.88	0		
SDSSCGA00008.4	587736543103877674	16	10	3.1	+5	54	45.2	16.61	1.00	0		
SDSSCGA00009.1	587735696979656747	12	3	13.8	+57	53	26.0	14.95	0.56	370085969178656768	1.000	0.034
SDSSCGA00009.2	587735696979656750	12	3	12.5	+57	53	36.4	15.02	0.48	0		
SDSSCGA00009.3	587735696979656749	12	3	13.4	+57	53	53.0	16.64	0.47	369803378328338432	0.995	0.034
SDSSCGA00009.4	587735696979656748	12	3	11.8	+57	53	41.2	17.34	1.64	0		
SDSSCGA00010.1	587736920508858742	16	26	50.6	+25	53	28.3	16.01	0.98	442988743981268992	1.000	0.110
SDSSCGA00010.2	587736899576725804	16	26	50.4	+25	53	39.6	16.97	1.09	0		
SDSSCGA00010.3	587736920508858744	16	26	49.7	+25	53	27.8	17.32	1.09	443271293421223936	1.000	0.112
SDSSCGA00010.4	587736899576725805	16	26	50.7	+25	53	43.1	17.82	0.81	0		
SDSSCGA00011.1	587736919434789305	16	21	57.1	+25	41	29.5	16.48	0.95	443834327290085376	1.000	0.099
SDSSCGA00011.2	587736919434789307	16	21	56.1	+25	41	19.1	16.76	1.11	0		
SDSSCGA00011.3	587736919434789306	16	21	56.2	+25	41	21.1	16.87	0.84	443271292800466944	0.999	0.100
SDSSCGA00011.4	587736919434789308	16	21	56.5	+25	41	10.9	17.26	0.56	443552841290743808	0.947	0.101
SDSSCGA00012.1	587738372204396691	7	44	43.3	+16	55	21.3	15.36	0.92	0		
SDSSCGA00012.2	587738372204396692	7	44	42.4	+16	55	38.5	15.95	0.85	0		
SDSSCGA00012.3	587738372204396694	7	44	41.9	+16	55	20.6	17.23	0.91	0		
SDSSCGA00012.4	587738372204396693	7	44	43.0	+16	55	5.8	17.73	0.86	0		

Table 3. Individual member galaxies in each compact group found in Catalogue A. Groups are listed in the same order as Table 1; galaxies in each group are listed in order of descending $r-$band luminosity. This table has 9713 rows, of which the first 48 rows are reproduced here (corresponding to the brightest 12 compact groups). See Section 2.5 for a description of each column.

(v) Of the remaining 148 groups, 11 have a magnitude range in the $r-$band (Δm) of greater than 3 magnitudes in the SDSS DR6. Thus these groups will not be identified in our catalogue using the Hickson criteria, and we do not consider them further;

(vi) Of the remaining 137 groups, 58 do not match the isolation criteria for selection as a compact group using the SDSS DR6. Thus these groups will not be identified in our catalogue and we do not consider them further.

We conclude that, of the original 175 groups identified by Lee et al. (2004), 96 are not identified in SDSS DR6. This is due to a different photometric classification of member objects (and nearby neighbours), which results in a failure of the group to meet the Hickson criteria in our SDSS DR6 galaxy catalogue.

Finally, we cross-correlate the remaining 79 compact groups from Lee et al. (2004) with the groups identified in Catalogue B (Tables 2 and 4). We identify all 79 groups,

ID	ObjID (SDSS)	α (J2000)			δ (J2000)			r	$(g-r)$	SpecObjID (SDSS)	z_{conf}	z
SDSSCGB00001.1	588017977829097722	14	12	15.9	+35	50	55.3	16.01	1.18	0		
SDSSCGB00001.2	588017977829097728	14	12	15.8	+35	51	3.3	16.56	0.49	462691635159891968	0.989	0.059
SDSSCGB00001.3	588017977829097727	14	12	15.5	+35	50	59.0	16.69	0.44	0		
SDSSCGB00001.4	588017977829097726	14	12	16.2	+35	50	58.6	17.07	0.11	0		
SDSSCGB00002.1	587739849139683368	16	15	45.5	+54	40	22.2	15.35	0.50	0		
SDSSCGB00002.2	587739849139683374	16	15	46.2	+54	40	17.5	16.26	0.51	0		
SDSSCGB00002.3	587739849139683371	16	15	46.3	+54	40	22.5	16.34	0.74	0		
SDSSCGB00002.4	587739849139683372	16	15	45.6	+54	40	16.3	17.59	0.42	0		
SDSSCGB00003.1	587742903404986565	13	25	10.3	+17	3	12.0	15.05	0.44	0		
SDSSCGB00003.2	587742903404986567	13	25	10.4	+17	3	0.9	16.60	0.14	0		
SDSSCGB00003.3	587742903404986570	13	25	10.9	+17	3	8.4	16.92	0.45	0		
SDSSCGB00003.4	587742903404986568	13	25	9.9	+17	3	10.8	17.32	0.45	0		
SDSSCGB00004.1	587741601491714194	11	44	12.2	+27	0	8.1	16.41	0.77	0		
SDSSCGB00004.2	587741708883329169	11	44	12.3	+27	0	11.8	17.12	0.78	0		
SDSSCGB00004.3	587741708883329171	11	44	11.8	+27	0	11.4	17.27	0.31	625386958805270528	0.978	0.093
SDSSCGB00004.4	587741708883329170	11	44	12.3	+27	0	16.6	18.02	0.14	0		
SDSSCGB00005.1	587741816231690635	7	55	29.9	+10	25	51.9	15.11	0.92	0		
SDSSCGB00005.2	587741816231690639	7	55	30.2	+10	25	46.5	15.81	0.35	0		
SDSSCGB00005.3	587741816231690637	7	55	30.7	+10	25	51.4	16.57	1.11	0		
SDSSCGB00005.4	587741816231690644	7	55	30.9	+10	25	57.4	17.96	0.32	0		
SDSSCGB00006.1	587744727686381596	9	4	34.8	+14	35	36.3	15.14	0.59	0		
SDSSCGB00006.2	587744727686381602	9	4	34.4	+14	35	39.4	15.38	0.13	685341276190539776	0.993	0.050
SDSSCGB00006.3	587744727686381597	9	4	34.6	+14	35	52.4	15.51	0.76	0		
SDSSCGB00006.4	587744727686381607	9	4	35.3	+14	35	38.8	17.40	1.55	0		
SDSSCGB00006.5	587744727686381610	9	4	35.5	+14	35	45.1	17.49	0.16	0		
SDSSCGB00007.1	588017726021369993	13	54	19.7	+7	23	12.4	15.62	0.89	508293726485872640	0.999	0.075
SDSSCGB00007.2	588017726021369994	13	54	19.1	+7	23	3.7	16.59	0.87	0		
SDSSCGB00007.3	588017726021369995	13	54	19.4	+7	23	15.3	17.81	0.59	0		
SDSSCGB00007.4	588017726021369996	13	54	19.7	+7	23	2.1	18.51	0.67	0		
SDSSCGB00008.1	587732577238712466	11	4	36.9	+6	23	42.1	15.43	0.39	0		
SDSSCGB00008.2	587732577238712469	11	4	36.6	+6	23	51.9	17.53	0.20	282545493425258496	0.987	0.032
SDSSCGB00008.3	587732577238712473	11	4	36.2	+6	23	45.3	17.63	-0.04	0		
SDSSCGB00008.4	587732577238712467	11	4	37.2	+6	23	45.2	17.70	0.07	0		
SDSSCGB00009.1	587729652347961399	16	28	27.9	+41	13	3.5	14.61	0.45	0		
SDSSCGB00009.2	587729652347961408	16	28	28.7	+41	12	55.6	16.10	-0.10	0		
SDSSCGB00009.3	587729652347961407	16	28	28.6	+41	13	11.8	16.15	-0.00	0		
SDSSCGB00009.4	587729652347961398	16	28	28.0	+41	13	13.7	16.26	0.08	229908547784146944	0.988	0.028
SDSSCGB00010.1	587742888898920722	16	13	18.9	+50	2	15.1	18.78	1.42	0		
SDSSCGB00010.2	587729226885497049	16	13	18.9	+50	2	15.2	18.80	1.60	0		
SDSSCGB00010.3	587742888898920723	16	13	18.9	+50	2	10.3	19.42	1.28	0		
SDSSCGB00010.4	587729226885497050	16	13	19.0	+50	2	10.3	19.58	1.17	0		
SDSSCGB00011.1	587729776371761364	14	29	17.6	-3	9	6.5	16.03	0.83	0		
SDSSCGB00011.2	587729776371761362	14	29	17.7	-3	9	21.3	16.04	0.92	0		
SDSSCGB00011.3	587729776371761366	14	29	17.3	-3	9	7.5	16.42	1.01	0		
SDSSCGB00011.4	587729776371761363	14	29	16.8	-3	9	17.9	16.68	1.51	2586191022711111168	1.000	0.082
SDSSCGB00012.1	588298663042941007	13	39	45.1	+45	39	58.8	18.08	0.51	0		
SDSSCGB00012.2	588298663042941006	13	39	44.8	+45	39	57.8	19.16	0.70	0		
SDSSCGB00012.3	588298663042941005	13	39	44.7	+45	39	58.7	20.15	2.18	0		
SDSSCGB00012.4	588298663042941010	13	39	45.0	+45	40	0.4	20.16	0.90	0		

Table 4. Individual member galaxies in each compact group found in Catalogue B. Groups are listed in the same order as Table 1; galaxies in each group are listed in order of descending $r-$band luminosity. This table has 313508 rows, of which the first 49 rows are reproduced here (corresponding to the brightest 12 compact groups). See Section 2.5 for a description of each column.

demonstrating that our procedure for identifying compact groups in SDSS DR6 is consistent with the earlier study using the SDSS EDR.

3   BASIC PROPERTIES OF THE SDSS DR6 COMPACT GROUP CATALOGUE

3.1   Number of galaxies per group

Figure 4 shows the distribution of the number of galaxies per group for Catalogue A (left panel) and Catalogue B (right panel). Blank histograms show the complete samples, whereas the hatched histograms show the distribution for
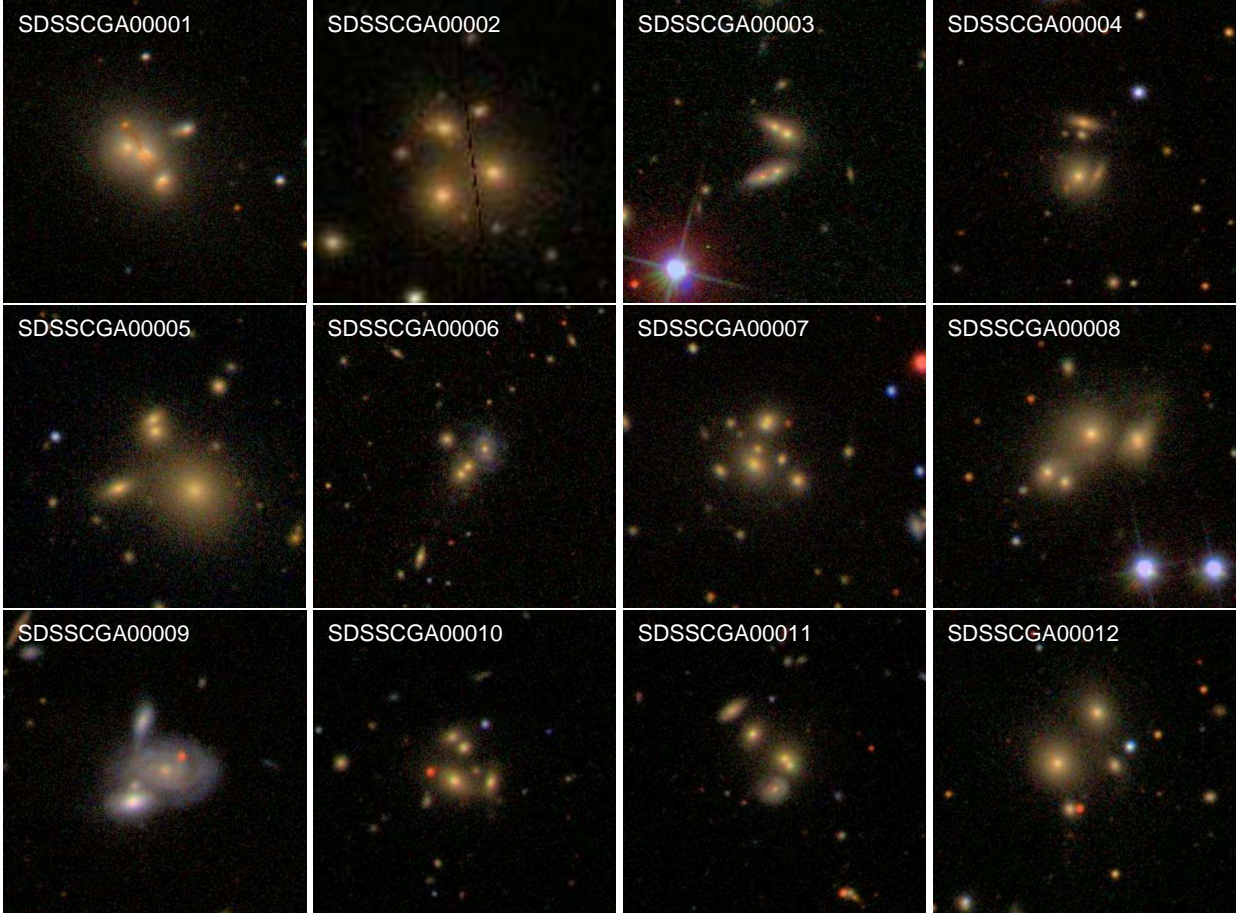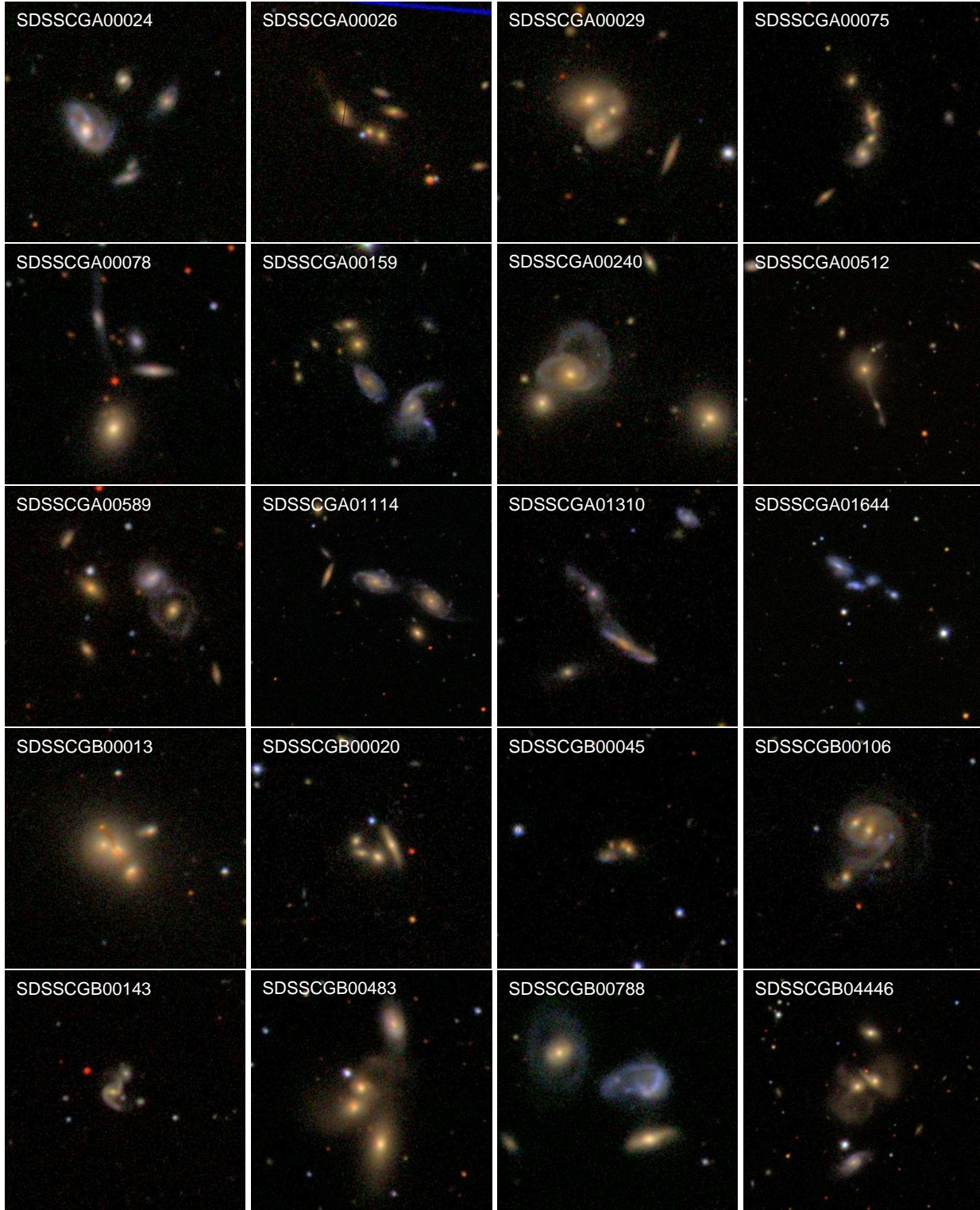
Figure 2. SDSS finding chart images of the twelve compact groups found in Catalogue A with the highest central surface brightnesses which are listed in Table 1. Each image is 1.7×1.7 arcmins.
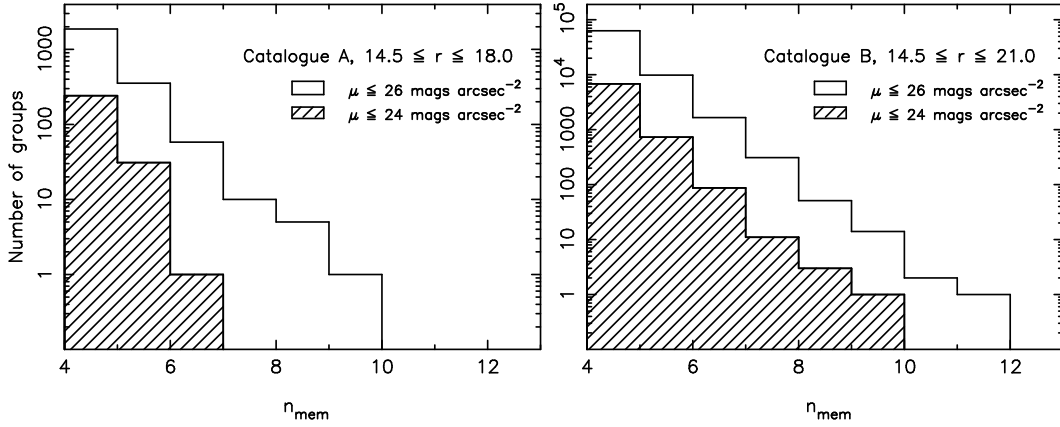
| | Catalogue A | | | | Catalogue B | | | |
| | $\Delta v < \infty$ | | $\Delta v \leq 1000$ km s^{-1} | | $\Delta v < \infty$ | | $\Delta v \leq 1000$ km s^{-1} | |
n_z	n_{grps}	n_{gals}	n_{grps}	n_{gals}	n_{grps}	n_{gals}	n_{grps}	n_{gals}
0	500	2115	500	2115	60516	252805	60516	252805
> 0	1797	4108	1008	1915	14275	16405	13414	14414
1	373	373	373	373	12537	12537	12537	12537
2	776	1552	422	844	1419	2838	772	1544
3	439	1317	159	477	251	753	87	261
4	183	732	49	196	63	252	18	72
5	23	115	5	25	5	25	0	0
6	2	12	0	0	0	0	0	0
7	1	7	0	0	0	0	0	0
n_{mem}	148	613	34	139	54	220	13	52

Table 5. The number of groups, n_{grps}, with n_z redshifts per group ($z_{conf} \geq 0.7$; also listed is the number of individual galaxies this represents in each case, n_{gal}). The first two columns for each catalogue gives these numbers irrespective of whether multiple redshifts per group agree with each other or not ($\Delta v < \infty$); the last two columns require $\Delta v \leq 1000$ km s^{-1}.

Figure 3. SDSS finding chart images of a selection of the compact groups in our catalogues, which show the diversity of the identified systems. Each image is 1.7×1.7 arcmins, except SDSSCGA01114 and SDSSCGA01644, which are 3.4×3.4 arcmins, and SDSSCGB04446, which is 2.6×2.6 arcmins.

Figure 4. Distribution of number of galaxies in each group identified in Catalogues A and B (left and right panels, respectively) for two different cuts in group surface brightness, $\mu \leq 26 \, \mathrm{mags \, arcsec^{-2}}$ (blank histogram) and $\mu \leq 24 \, \mathrm{mags \, arcsec^{-2}}$ (hatched histogram).

those groups where $\mu \leq 24 \, \mathrm{mags \, arcsec^{-2}}$. The fraction of groups which contain galaxies at discordant redshifts (that is, chance line-of-sight alignments rather than physically dense groups) is expected to be greatly reduced for this latter sample. Clearly, the overwhelming majority of groups from both Catalogues A and B have 6 members or less; very few groups in the brighter subsamples have more than 5 members, strongly suggesting that groups more numerous than this contain interlopers, at least in part. If groups with more than 6 genuine members exist, they are intrinsically very rare.

3.2 Group surface brightness

The left panel of Figure 5 shows the $r-$band group surface brightness distribution for all groups identified in Catalogue A, and the right panel shows the same for all groups identified in Catalogue B. More groups are found at lower surface brightness; however, as shown in Paper I, brighter groups are more likely to be genuine and not contain any interlopers (see Section 3.3.2 for a more detailed investigation of this point).

3.3 Spectroscopic Information

3.3.1 Spectral Completeness

The compact groups and their member galaxies presented in Tables $1 - 4$ were selected based on their photometric properties, in particular their projected positions and $r-$band apparent magnitudes. However, the SDSS DR6 has spectroscopic information available for 1.27 million objects, of which 679733 objects are galaxies which satisfy our criteria for inclusion in Catalogue B. Thus, many of the galaxies we identify as being a member of a compact group will have spectroscopic data available.

For the groups identified in Catalogue A, 4131 out of 9713 member galaxies (43 %) have spectroscopic information available, 4108 of which yield a reliable redshift ($z_{conf} \geq 0.7$). For groups identified in Catalogue B, 16566
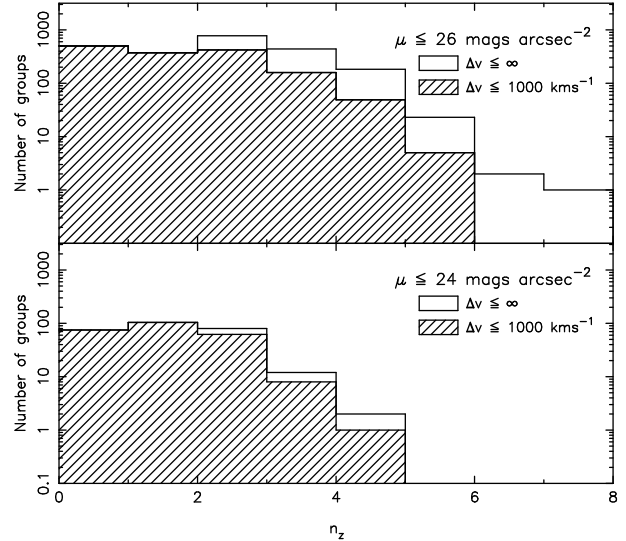
Figure 6. Top panel: The blank histogram shows the distribution of the number of galaxies with reliable redshifts per group ($z_{conf} \geq 0.7$), for compact groups identified in Catalogue A. The hatched histogram shows the same distribution but with the additional constraint that $\Delta v \leq 1000 \, \mathrm{km \, s^{-1}}$ (ie., we ignore groups with discordant velocity data). Bottom panel: Same as top panel, except only using groups where $\mu \leq 24 \, \mathrm{mags \, arcsec^{-2}}$.

out of 313508 member galaxies (5 %) have spectroscopic information available, 16405 of which yield a reliable redshift. The fraction of galaxies with spectroscopic data available in Catalogue B is significantly less than in Catalogue A, since Catalogue A contains a higher fraction of brighter galaxies (which are preferentially selected as spectroscopic targets).

3.3.2 Estimate of interloper fractions

Table 5 lists the number of groups, n_{grps}, with n_z redshifts per group, as well as the number of individual galaxies this represents in each case, n_{gals}. We only consider galaxies
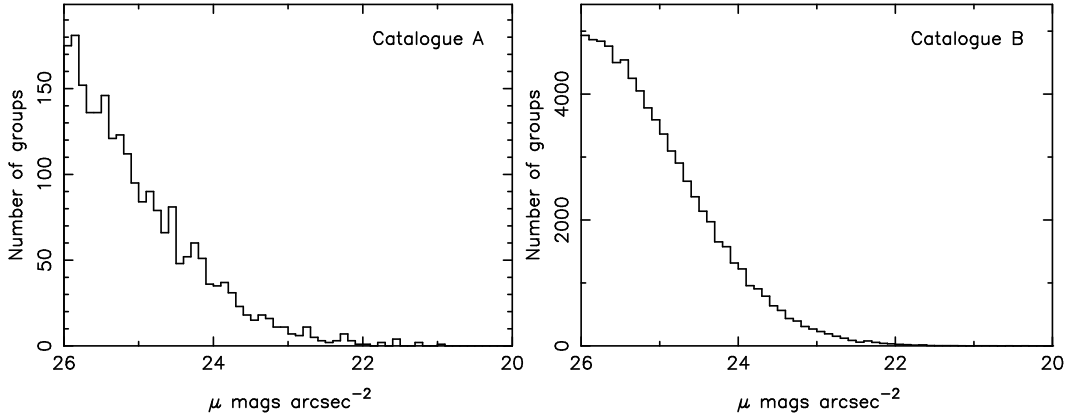
Figure 5. The distribution of group surface brightness in the $r-$band for all groups identified in Catalogue A (left panel) and Catalogue B (right panel).
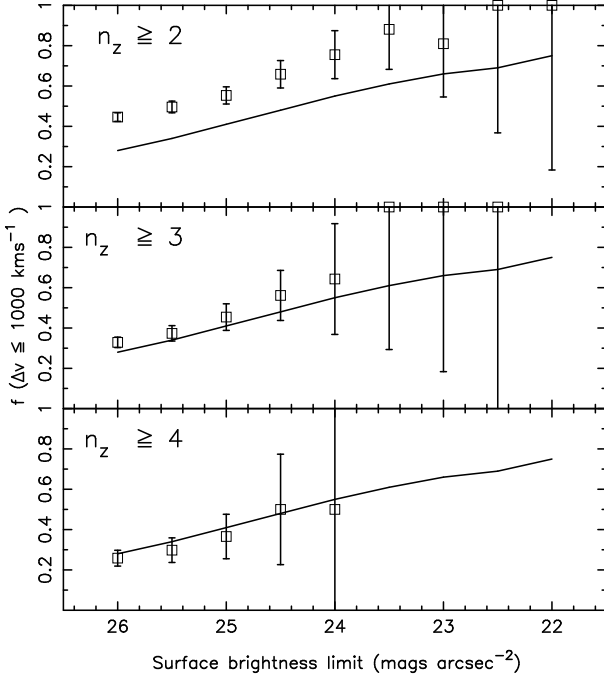
Figure 7. For groups identified in Catalogue A with multiple redshifts, points show how the fraction of groups with concordant redshifts ($\Delta v \leq 1000$ km s^{-1}) varies as a function of the surface brightness detection limit. Vertical error bars are Poisson uncertainties. The solid lines show the *predicted* fraction of groups with concordant redshifts (ie. no interlopers) from our mock catalogue study in Paper I. The fraction of groups with concordant redshifts decreases for groups with higher n_z since it is more likely that an interloping galaxy will be targeted. For groups with $n_z \geq 3, 4$, the observed and predicted number of groups with interlopers agree remarkably well.

where $z_{conf} \geq 0.7$. This information is listed for two different cuts in Δv, where we define

$$\Delta v = 0 , \quad n_z \leq 1$$

$$\Delta v = max\left[|cz_i - cz_j|/(1 + z_{ij})\right] , \quad n_z \geq 2. \quad (1)$$

$z_{ij} = (z_i + z_j)/2$, $i, j = 1...n_z$, $i \neq j$, and so Δv is a measure of the maximum line-of-sight velocity difference between group members for groups where $n_z \geq 2$. The cut $\Delta v \leq 1000$ km s^{-1} selects only those groups where multiple redshifts (if available) are concordant. This removes groups which contain interloping galaxies which happen to lie along the same line-of-sight. As was demonstrated in Paper II (and assumed in most previous studies of compact groups; e.g. Hickson et al. 1992), few, if any, genuine compact groups are expected to possess members with line-of-sight velocity differences in excess of 1000 km s^{-1}.

The blank histogram in the top panel of Figure 6 shows the distribution of n_z for compact groups identified in Catalogue A. The hatched histogram shows the same distribution but with the additional constraint that $\Delta v \leq 1000$ km s^{-1}. The bottom panel of Figure 6 shows the same distributions but only considers those groups with $\mu \leq 24$ mags arcsec^{-2}. Results from Paper I suggests that the fraction of identified groups which contain interlopers decreases from 71% for $\mu \leq 26$ mags arcsec^{-2} to 44% for $\mu \leq 24$ mags arcsec^{-2}.

Table 5 and Figure 6 demonstrate that the majority of groups which have redshift measurements for multiple members have discordant redshifts ($\sim 55\%$ in Catalogue A), implying that *at least* 55 % of identified groups in Catalogue A contain interlopers. For the brighter sub-sample of groups with $\mu \leq 24$ mags arcsec^{-2}, a smaller fraction of groups with multiple redshifts has discordant redshifts ($\sim 24\%$). These results are qualitatively consistent with the expected contamination rates discussed in Paper I.

The solid lines in Figure 7 show the *predicted* fraction of interloper-free compact groups recovered as a function of the limiting surface brightness of the groups (calculated in Paper I and listed in Table 1 of that paper). For example, when considering all groups brighter than $\mu = 24$ mags arcsec^{-2}, we expect that 44% of those groups will contain interlopers. For groups from Catalogue A with $n_z \geq 2$, the points in Figure 7 shows the fraction with multiple *concordant* redshifts as a function of the limiting group surface brightness. Ver-
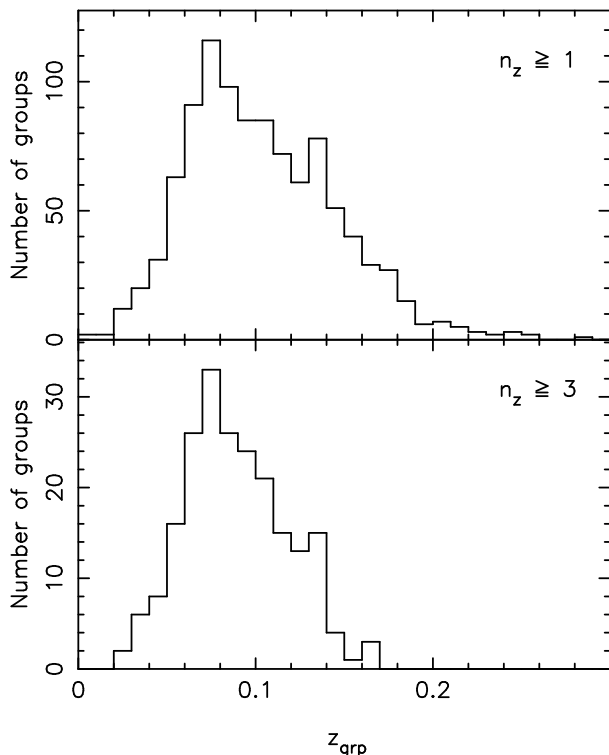
Figure 8. Mean redshift distribution of compact groups from Catalogue A, for those groups with redshift measurements where $z_{conf} \geq 0.7$. Only those groups with $\Delta v \leq 1000 \, \mathrm{km \, s^{-1}}$ are shown. The top panel shows those groups for which there exists a redshift measurement for at least one galaxy. The lower panel shows those groups for which at least 3 galaxies per group have a redshift measurement. The latter distribution is least likely to contain groups with interloping galaxies.

tical error bars show the Poisson uncertainties. The three panels show results for different values of n_z.

Despite the fact that full redshift information (ie., $n_z = n_{mem}$) is not available for most groups, Figure 7 demonstrates that the predicted interloper fractions from Paper I appear in good agreement with the best estimates for interloper fractions for groups identified in Catalogue A. The observed interloper fraction and the predicted one are in best agreement for higher n_z, since it is the more likely the interloper(s), if present, will have been targeted for spectroscopy. Figure 7 thus presents strong empirical evidence that the selection of groups by their surface brightness can greatly reduce the fraction of interloping galaxies/groups present.

3.3.3 Redshift distribution of groups identified in Catalogue A

Figure 8 shows the mean redshift distribution for all compact groups from Catalogue A with redshift measurements where $z_{conf} \geq 0.7$. Only groups for which $\Delta v \leq 1000 \, \mathrm{km \, s^{-1}}$ are shown. The top panel shows those groups for which there exists a redshift measurement for at least one galaxy. The lower panel shows those groups for which at least 3 galaxies
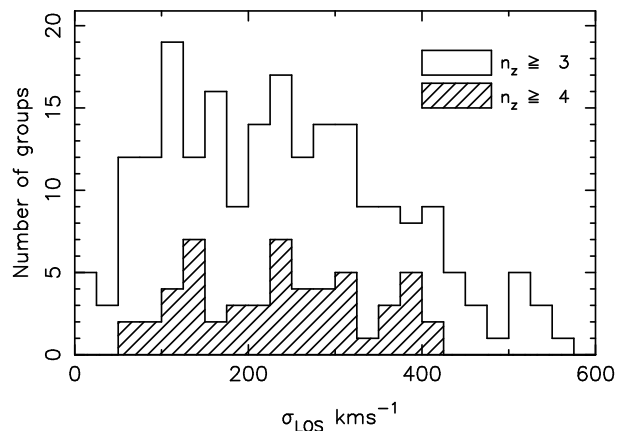
Figure 9. Line-of-sight velocity dispersions for all groups from Catalogue A with $n_z \geq 3, 4$ (blank and hatched histograms, respectively) with concordant redshift information. A K-S test reveals that the two distributions are statistically similar.

per group have a redshift measurement. The lower distribution is less likely to contain redshifts of groups with interloping galaxies due to its higher spectroscopic completeness.

The peak (modal) redshift of the groups in each panel of Figure 8 is $z_{peak} = 0.07 - 0.08$. The median redshift of all groups with at least one redshift is $z_{med} \simeq 0.1$, while for those with at least 3 concordant redshifts it is $z_{med} \simeq 0.09$ (for comparison, the median redshift of the Lee et al. (2004) sample is $z_{med} \approx 0.13$). We note that the classical sample of Hickson compact groups (Hickson 1982) have a considerably lower median redshift than these samples, with a median redshift of $z_{med} \sim 0.03$ (Hickson et al. 1992).

A K-S test shows that the distributions in the two panels of Figure 8 are unlikely to have been drawn from the same underlying distribution at the $> 99.9\%$ level. In particular, the fraction of groups with $z > 0.1$ in the $n_z \geq 3$ sample is much less than in the $n_z \geq 1$ sample. It is therefore probable that all genuine groups found in Catalogue A have $z \lesssim 0.17$, the maximum redshift of groups in the $n_z \geq 3$ sample.

3.3.4 Velocity dispersions of groups identified in Catalogue A

Figure 9 shows the physical line-of-sight velocity dispersions (σ_{LOS}) for all groups from Catalogue A with $n_z \geq 3, 4$ (blank and hatched histograms, respectively) with concordant redshift information. A K-S test shows that the two distributions are statistically similar. Although $\Delta v \leq 1000 \, \mathrm{km \, s^{-1}}$ is required for a group to be included in these histograms, most groups have velocity dispersions significantly smaller than this; the maximum velocity dispersion of groups with $n_z = 3(4)$ is $\sigma_{LOS} = 546 \, \mathrm{km \, s^{-1}} (395 \, \mathrm{km \, s^{-1}})$. The median velocity dispersion of groups with $n_z = 3(4)$ is $\sigma_{LOS} = 244 \, \mathrm{km \, s^{-1}} (227 \, \mathrm{km \, s^{-1}})$. These numbers compare favourably to the classical Hickson compact groups, which have a median velocity dispersion of $\sigma_{LOS} \simeq 200 \, \mathrm{km \, s^{-1}}$ (Hickson et al. 1992).

3.4   Number Density of Compact Groups

We identify 2297 compact groups in the SDSS DR6 down to a limiting magnitude of $r = 18$, corresponding to $\sim$ 0.24 groups degree^{-2}. 0.9% of galaxies down to this limiting magnitude are identified as a member of a compact group. From the redshift analysis in the previous section, we can expect $\sim 71\%$ of these compact groups to contain interlopers, and so the density of interloper-free compact groups is probably nearer ~ 0.07 groups degree^{-2}. However, most of the systems containing interlopers can still be expected to contain a close pair, triplet or higher-order multiple of galaxies (Paper I).

In Paper I, we identify 15122 compact groups in an all-sky mock catalogue with a limiting magnitude of $r = 18$ mags, the same as Catalogue A. The predicted density of identified groups in this catalogue is therefore $\sim$ 0.37 groups degree^{-2}, approximately 50% higher than the observed density in the SDSS DR6. Given that both the observed and mock catalogues were examined using an identical procedure, we surmise that this disparity is a result of inaccuracies in the modeling on which the mock catalogue is based. For example, it may be that the limited resolution of the Millennium simulation causes the merger time of close systems to be incorrectly estimated (see a discussion of these issues in Paper I and Springel et al. 2005). It should be noted that our investigation of the effect of interlopers (Section 3.2.2) and the results from Paper II suggest that many of the properties of the galaxies and groups identified in the mock catalogue are close to the observed properties. Future contributions dealing with the observed properties of the identified groups in SDSS DR6 will include comparisons to the mock catalogue, and may reveal where the source of the discrepancy lies.

Considering all galaxies down to a limiting magnitude of $r = 21$, we identify 74791 compact groups. Accounting for contamination from incorrect photometric classification (Section 2.4.2), this corresponds to ~ 6.7 groups degree^{-2}, with 0.9% of all galaxies down to this limiting magnitude identified as a member of a compact group. As the redshift study in the previous section makes clear, the majority of these groups will consist in part or in full of interloping galaxies along the same line-of-sight. While the fraction of groups with interlopers is predicted to be as high as 71% for a catalogue with a limiting magnitude of $r = 18$, we can expect that the interloper fraction will significantly increase for a catalogue with a fainter limiting magnitude (since the probability that a given line-of-sight will pass close to an unrelated galaxy will increase).

3.5   Density of the compact group environment

3.5.1   Angular size on sky

The left panel of Figure 10 shows the distribution of the projected radii (θ_G) of groups from Catalogue A. The blank histogram shows the distribution for all groups, whereas the hatched histogram shows the distribution for those groups with $\mu \leq 24$ mags arcsec^{-2}. Virtually all of these compact groups have $\theta_G < 2$ arcmins, and all groups with

$\mu \leq 24$ mags arcsec^{-2} have $\theta_G < 1$ arcmin. This reflects the fact that $\mu \propto \theta_G^{-2}$, as expected, and emphasizes the high apparent density of these groups.

### 3.5.2   Physical group radii and intergalactic separation

For those groups with concordant redshift information, we can calculate the de-projected physical radius of each group, $r_G = (D_M\theta_G)/(1 + z_{grp})$, where D_M is the transverse co-moving distance (following Hogg 1999). We assume $H_o = 70$ km s^{-1} Mpc^{-1}, $\Omega_\Lambda = 0.7$ and $\Omega_M = 0.3$. The blank histogram in the right panel of Figure 10 shows the distribution of group radii for all groups with the necessary redshift information identified in Catalogue A, and the hatched histogram shows the corresponding distribution for those groups with $\mu \leq 24$ mags arcsec^{-2}.

Groups detected in Catalogue A typically have $r_G \lesssim$ 200 kpc, and the sub-set with $\mu \leq 24$ mags arcsec^{-2} typically have $r_G \lesssim 100$ kpc. The mean radii of all the compact groups is $\bar{r}_G = 89.4 \pm 1.3$ kpc ($\bar{r}_G = 47.1 \pm 1.8$ kpc for the bright subset), where the uncertainty is the random error in the mean. We estimate the typical inter-galactic separation of individual galaxies within groups to be $\bar{r}_{sep} \simeq (\frac{4}{3}\pi\bar{r}_G^3/n_{mem})^{\frac{1}{3}}$. For $n_{mem} = 4$, this corresponds to $\bar{r}_{sep} \simeq 91$ kpc ($\bar{r}_{sep} \simeq 48$ kpc) for the main (bright) sample of groups from Catalogue A. This is significantly less than the expected virial radii of typical $L_\star$−type galaxies, and confirms the high spatial density of these environments.

4   SUMMARY

In this paper we have presented a publically available catalogue of compact groups of galaxies identified in the SDSS DR6 (Adelman-McCarthy et al. 2008) using the original Hickson criteria (Hickson 1982). We identify 2297 (74791) compact groups down to a limiting magnitude of $r = 18$ (21). 0.9% of all galaxies at both magnitude limits are identified as members of compact groups, although once interlopers are accounted for this fraction will decrease. Figures 2 and 3 show a selection of compact groups from our catalogue and illustrates the diversity of the groups in this sample. Many galaxies in these groups appear to be early-type, in agreement with previous studies (e.g. Hickson et al. 1988; Palumbo et al. 1995, Paper II), although there are many examples of groups with late-type members (many of them visually spectacular). A later paper in this series will investigate the detailed morphology of galaxies in these compact groups.

Spectroscopic information is available for 43 % (5 %) of compact group galaxies to a limiting magnitude of $r = 18$ (21); we find that the median redshift of the compact groups identified in Catalogue A is $z_{med} = 0.09$. The median line-of-sight velocity dispersions within groups from Catalogue A are $\sigma_{LOS} \simeq 220 - 250$ km s^{-1}. and the typical inter-galactic separations are of order $50 - 100$ kpc. The fraction of groups with interloping galaxies as members is significant, and is shown to be in good agreement with the predictions from the mock galaxy catalogue from Paper I, despite the latter
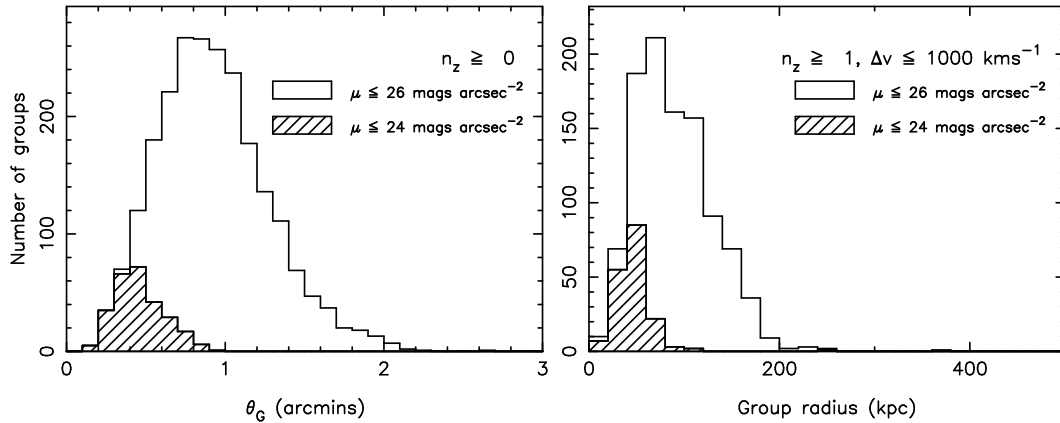
Figure 10. Left panel: the blank histogram shows the distribution of the angular projected radius (θ_G) of all identified groups in Catalogue A. The hatched histogram shows the distribution of θ_G for all groups from Catalogue A with $\mu \leq 24 \, \mathrm{mags\,arcsec}^{-2}$. Right panel: for groups from Catalogue A with concordant redshift information, the blank histogram shows the distribution of the physical group radius in kpc. The hatched histogram shows the same distribution for groups with $\mu \leq 24 \, \mathrm{mags\,arcsec}^{-2}$.

over-predicting the number density of compact groups by $\sim 50\%$. We empirically show that the selection of groups by group surface brightness can reduce the interloper fraction significantly; this will be a powerful tool for future studies of these catalogues.

The catalogue of compact groups derived in this paper is publically available: Tables 1 – 4 contain basic information for all the groups and member galaxies we identify, including the identifiers necessary to extract full information on each galaxy from the main SDSS DR6 database. Full versions of these tables are available for download from the MNRAS website.

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